DRAFT Preliminary Review: Navy Groundwater Flow Model for the Navy Red Hill Facility

By:

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Technical subject matter experts
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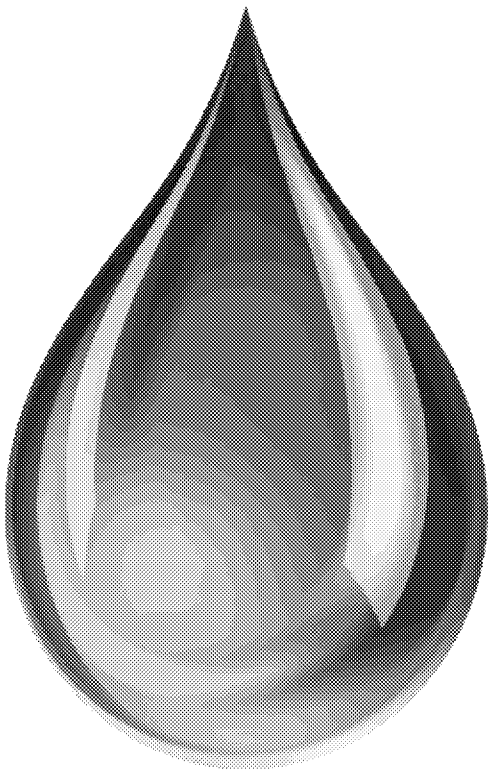
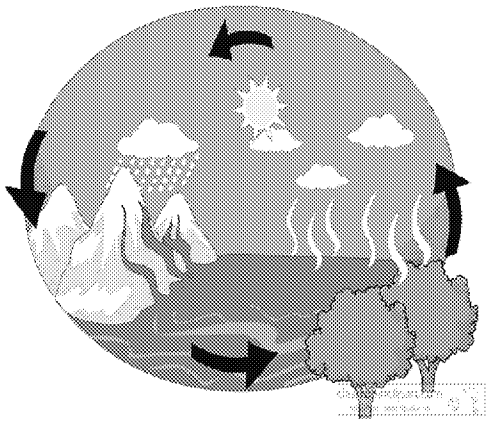
One Overarching Goal



- The purpose of this deliverable is to refine the existing groundwater flow model and improve the understanding of the direction and rate of groundwater flow within the aquifers around the Facility (AOC, 2015)
  - *To do this, the underlying geologic conditions must be refined and better understood in light of new data not available to prior modeling*

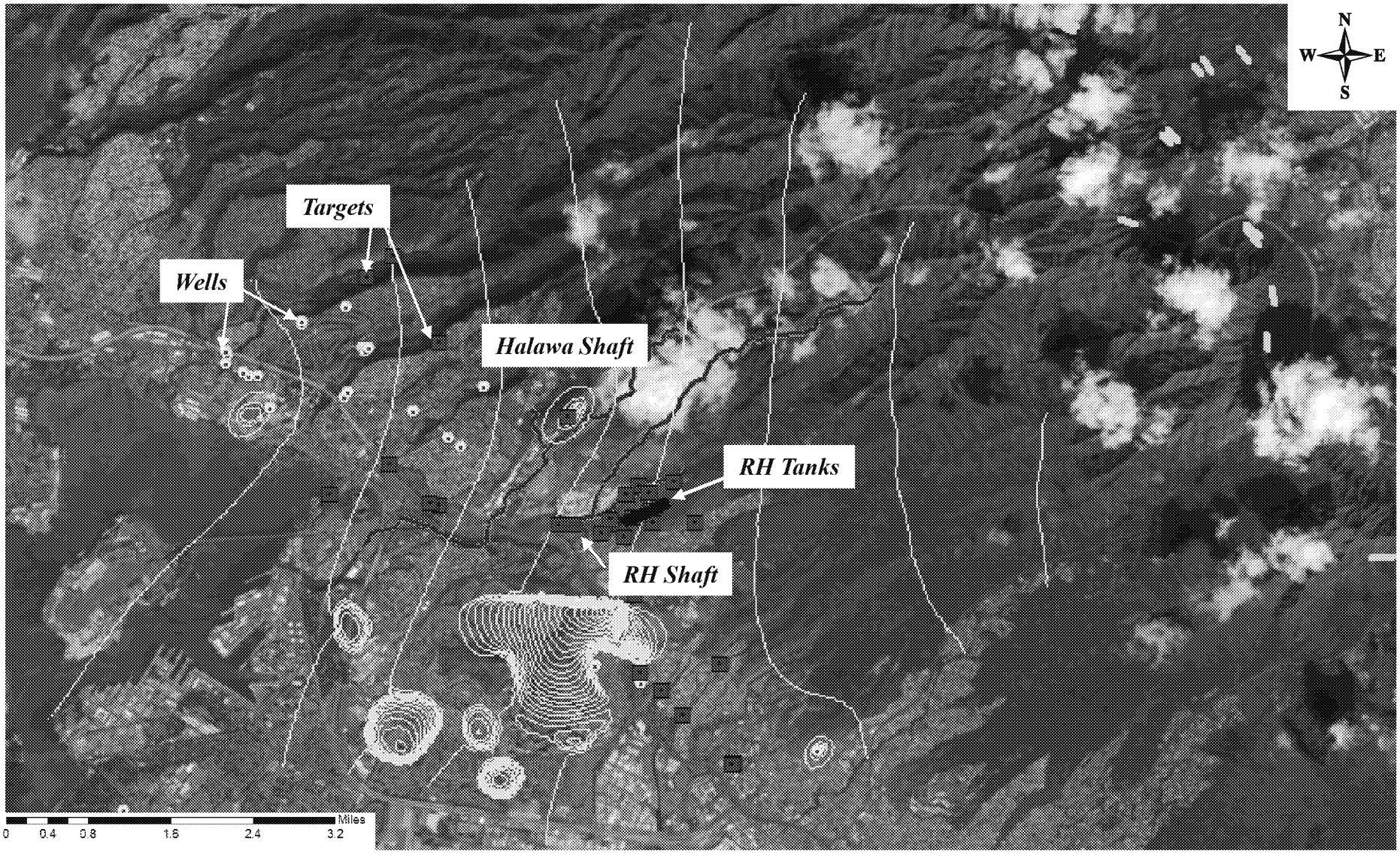
The Navy Has Delivered Multiple Models



- Key review questions:
  - Do the models represent local heads?
  - Do the models represent gradients?
  - Do the models reflect transient aspects?
    - Pumping from Red Hill & Halawa shafts
    - Monitoring well "groupings"
  - Do transient simulations better past models?
  - Are models consistent with geochemistry?
  - Are models consistent with COCs?
  - Are models parameters justified?
- Will the model inform risk estimates?
  - Most uncertain aspect is NAPL
    - Where is it presently & in what state?
    - How far/fast could releases travel?
  - Is there any basis for down-scaling?

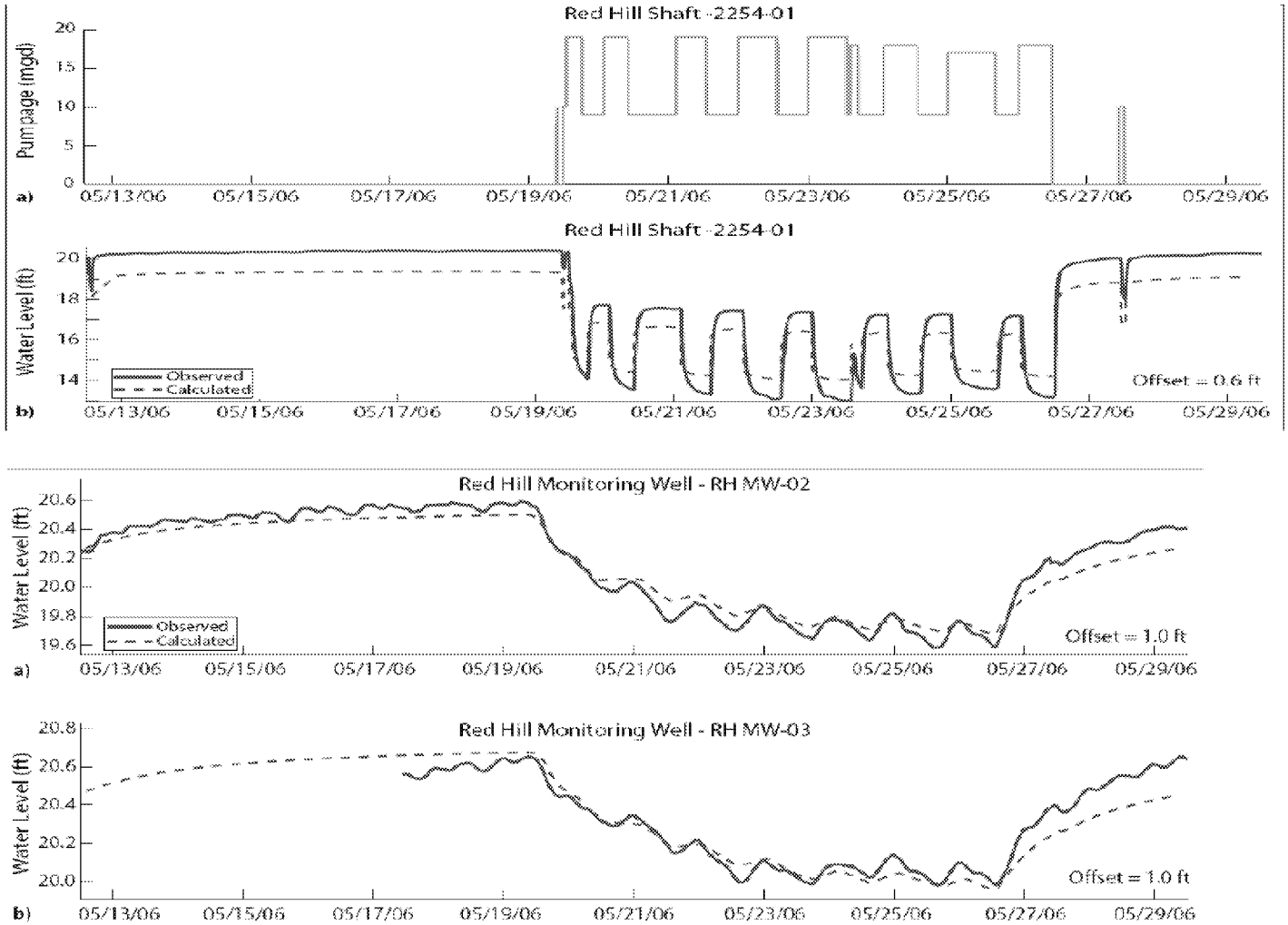
General Area/Model Map

(Halawa Shaft On, RH Shaft Off)



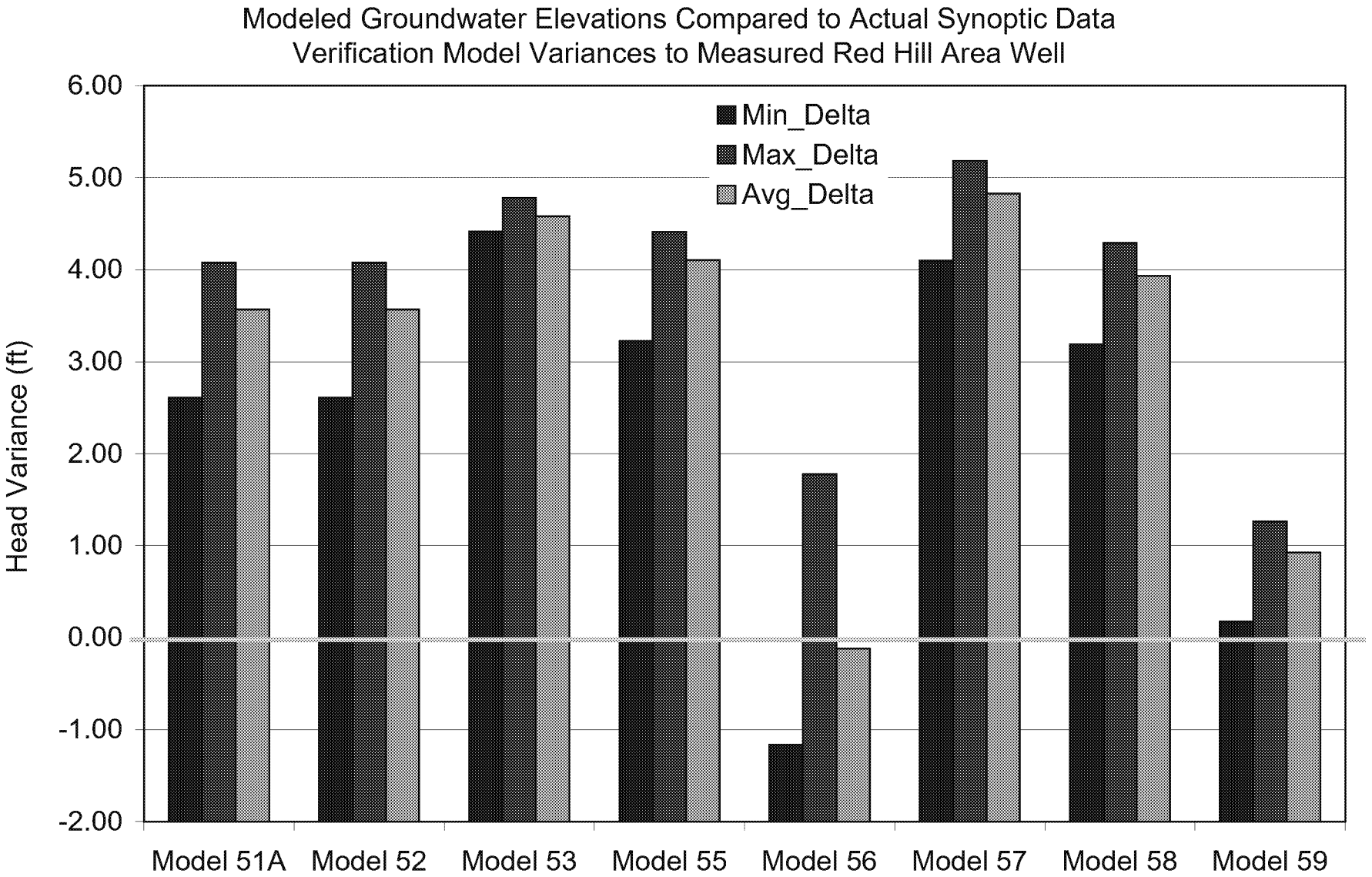
The Primary Issue with Prior Model

(calibrated to drawdown, but not to heads; complexity)

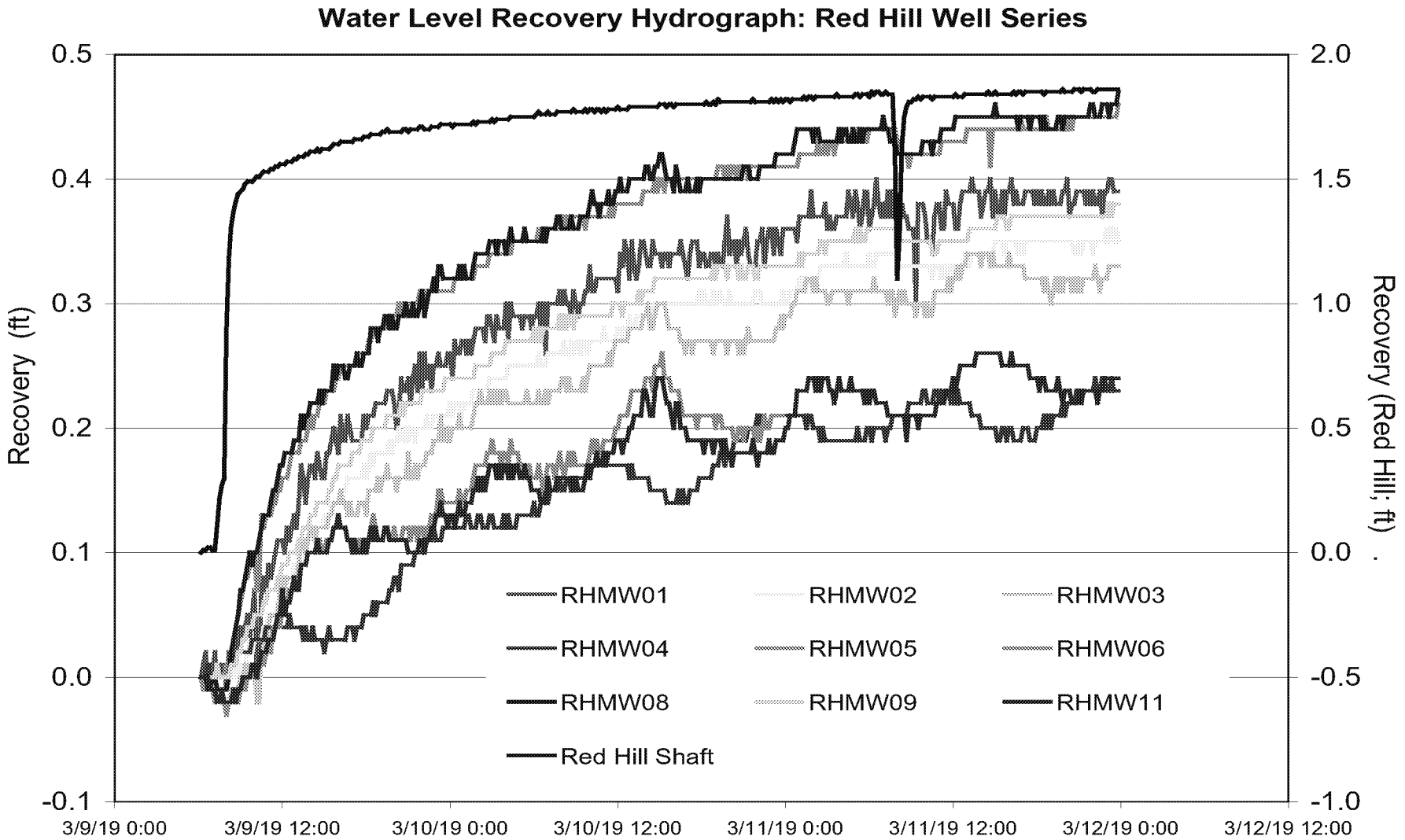


Kolja Rotzoll and Aly I. El-Kadi, 2007

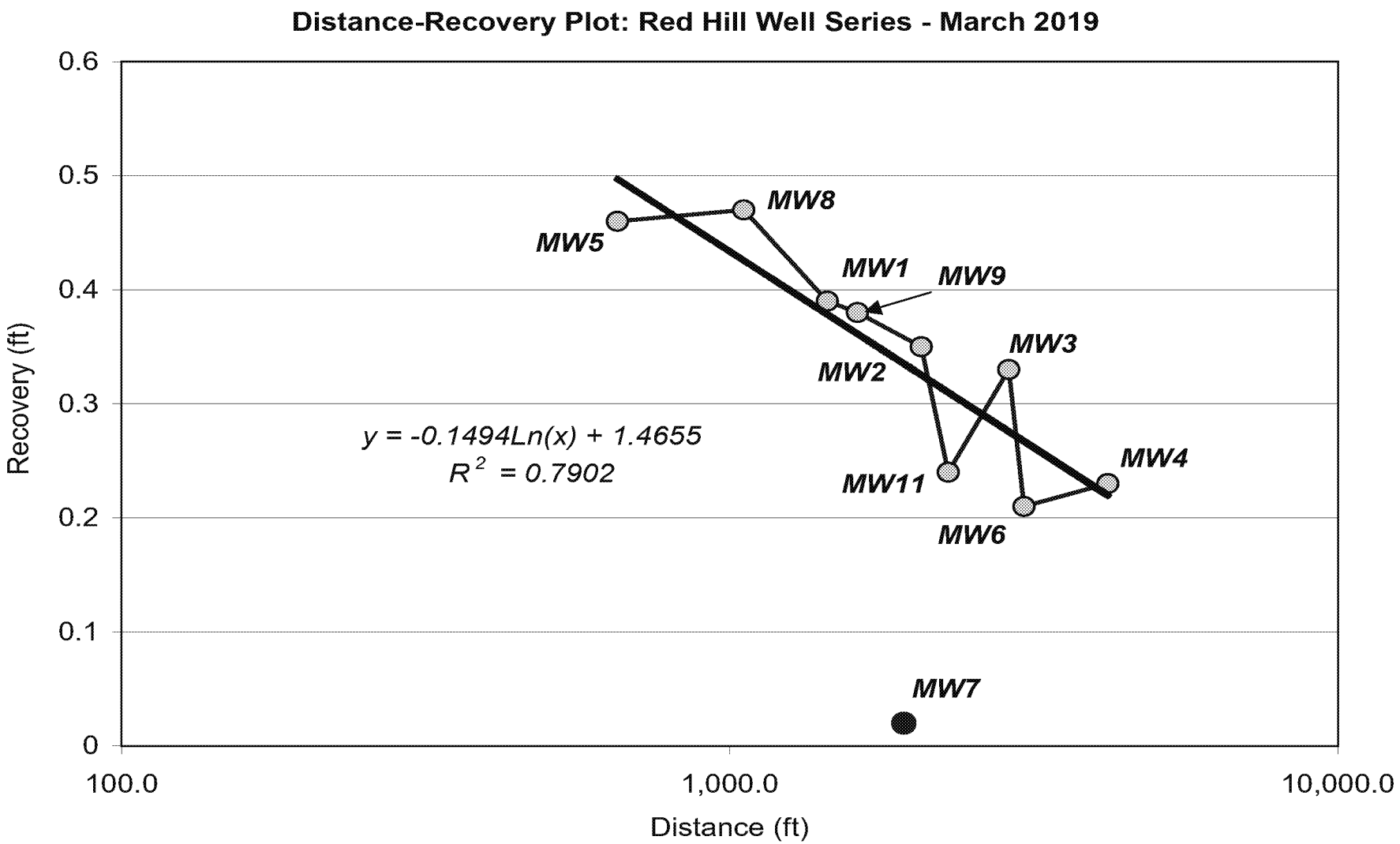
GW Elevation Variance – Transient Models



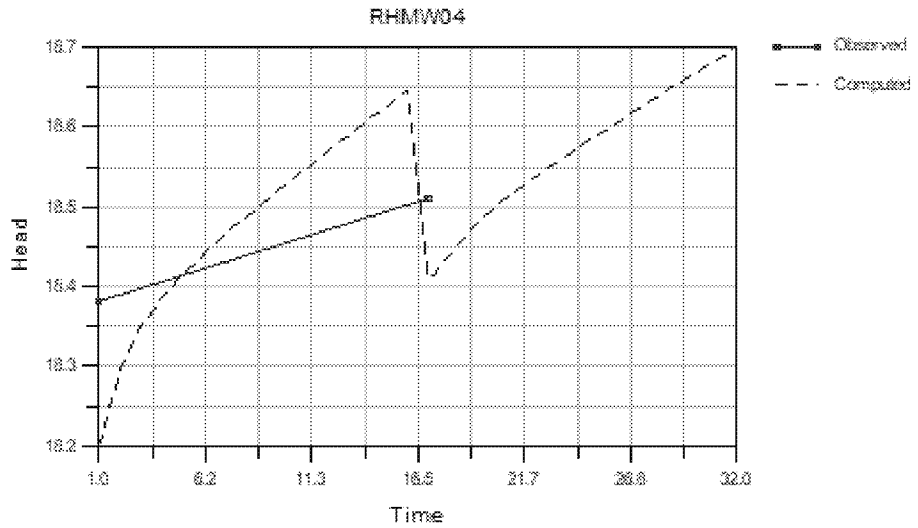
Well Response Differs in Various Wells

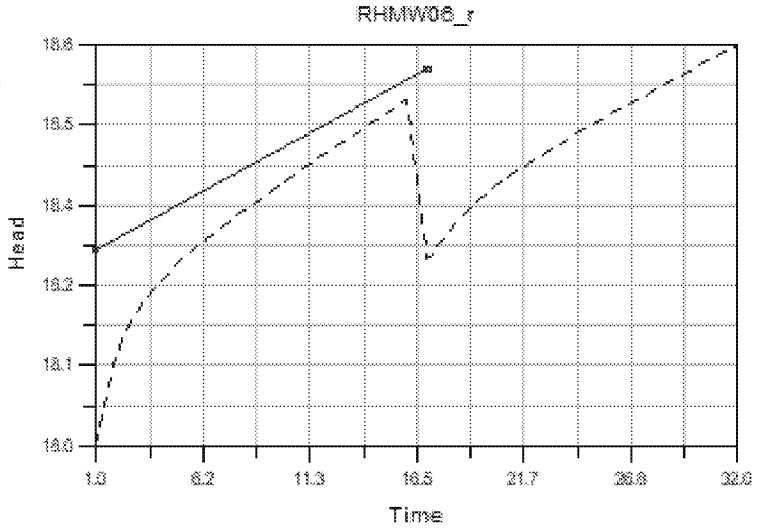


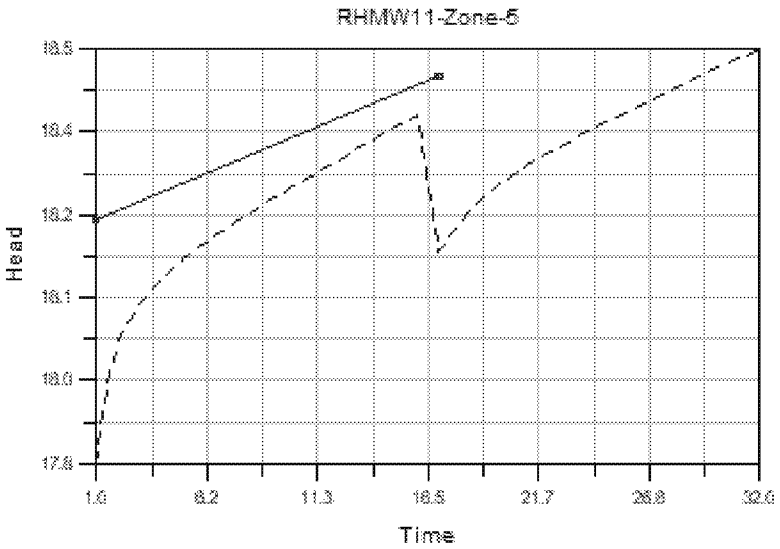
Non-Uniform Distance Drawdown Behavior

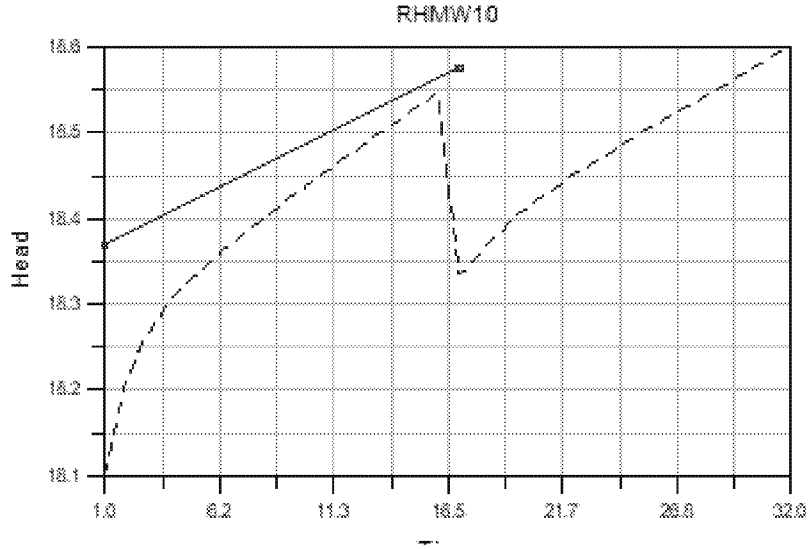


Example Hydrographs; M51a Base Case

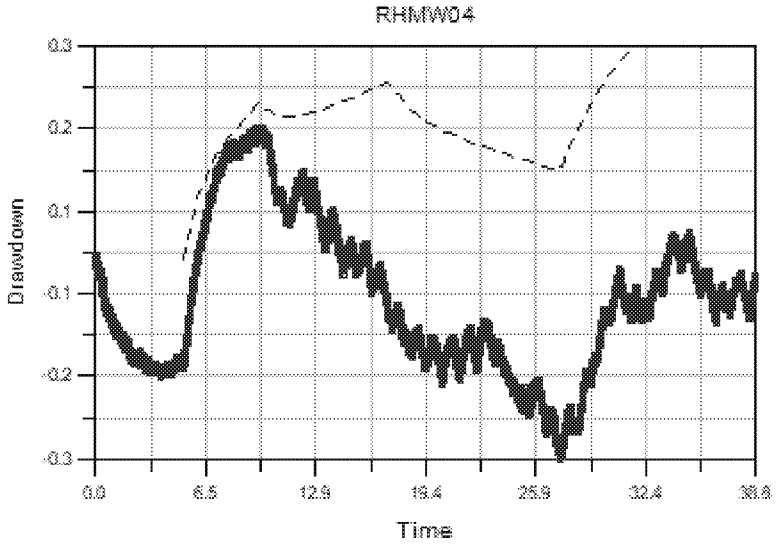


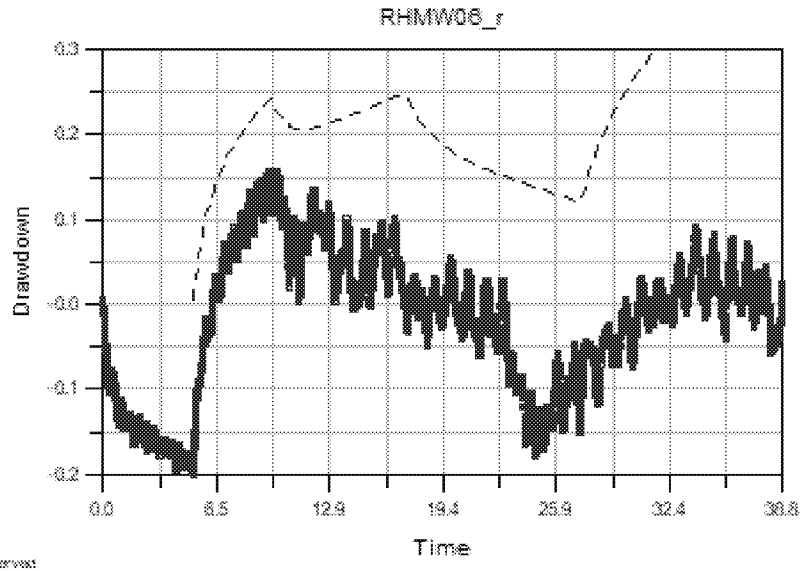


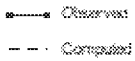


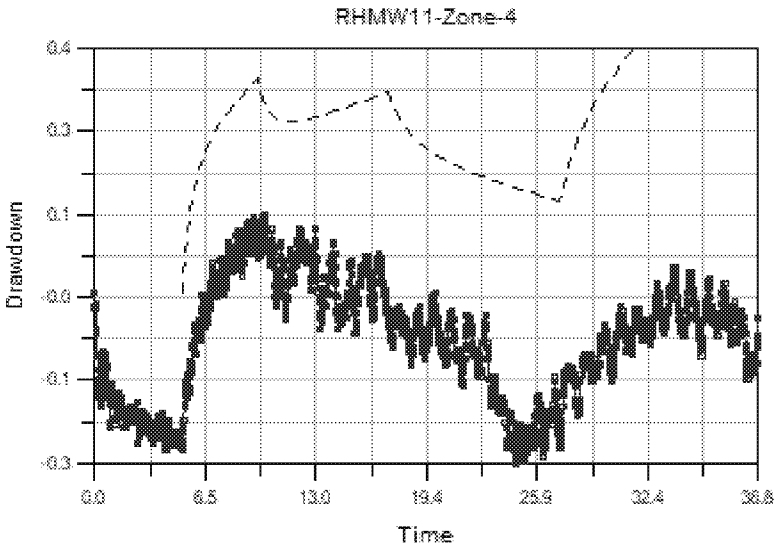


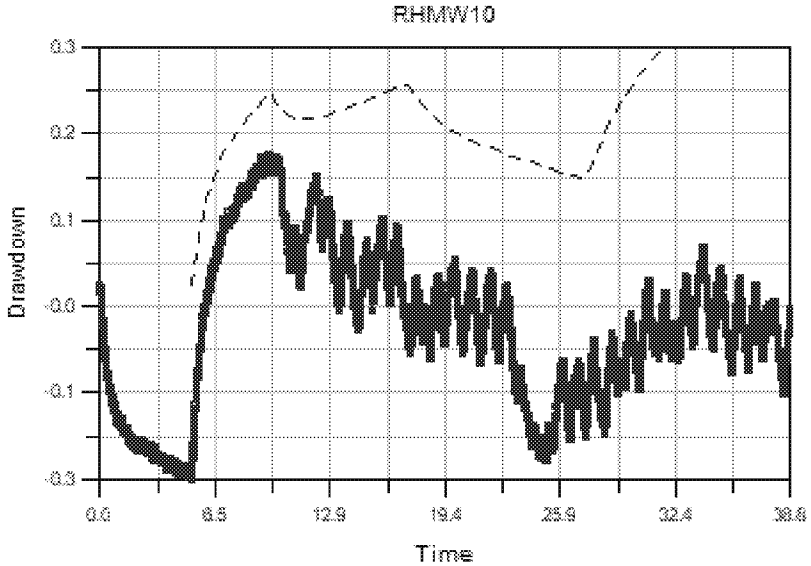
Example Hydrographs; M51a Verification









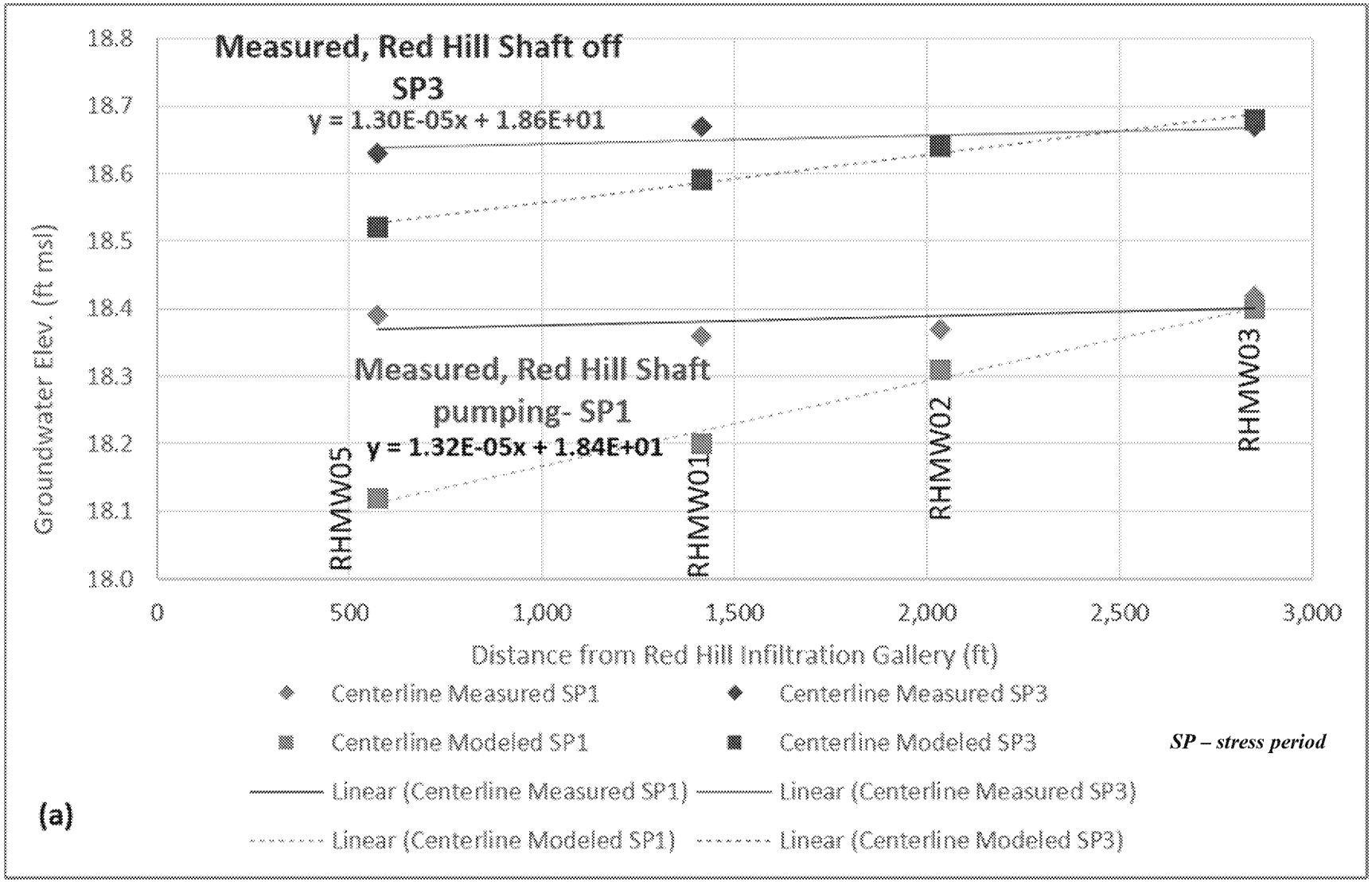


Prior Key Parameters v. Navy Models

	Oki, 2005			Navy GWFM - avgs		
Hydrostratigraphic Unit	Kv	Kt	Kl	Kv	Kt	Kl
Volcanic-rock aquifer	7.5	1,500	4,500	65	1,000	2,999
Caprock, upper-limestone unit	25	2,500	2,500	0.01	500	500
Caprock, low-permeability unit						
Above Waianae Volcanics	0.3	0.3	0.3	0.01	1	1
Above Koolau Basalt, west of Waiawa Stream	0.01	0.01	0.01	0.01	1	1
Above Koolau Basalt, east of Waiawa Stream	0.6	0.6	0.6	0.01	1	1
Valley-fill barriers	0.058	0.058	0.058	0.01	1	1

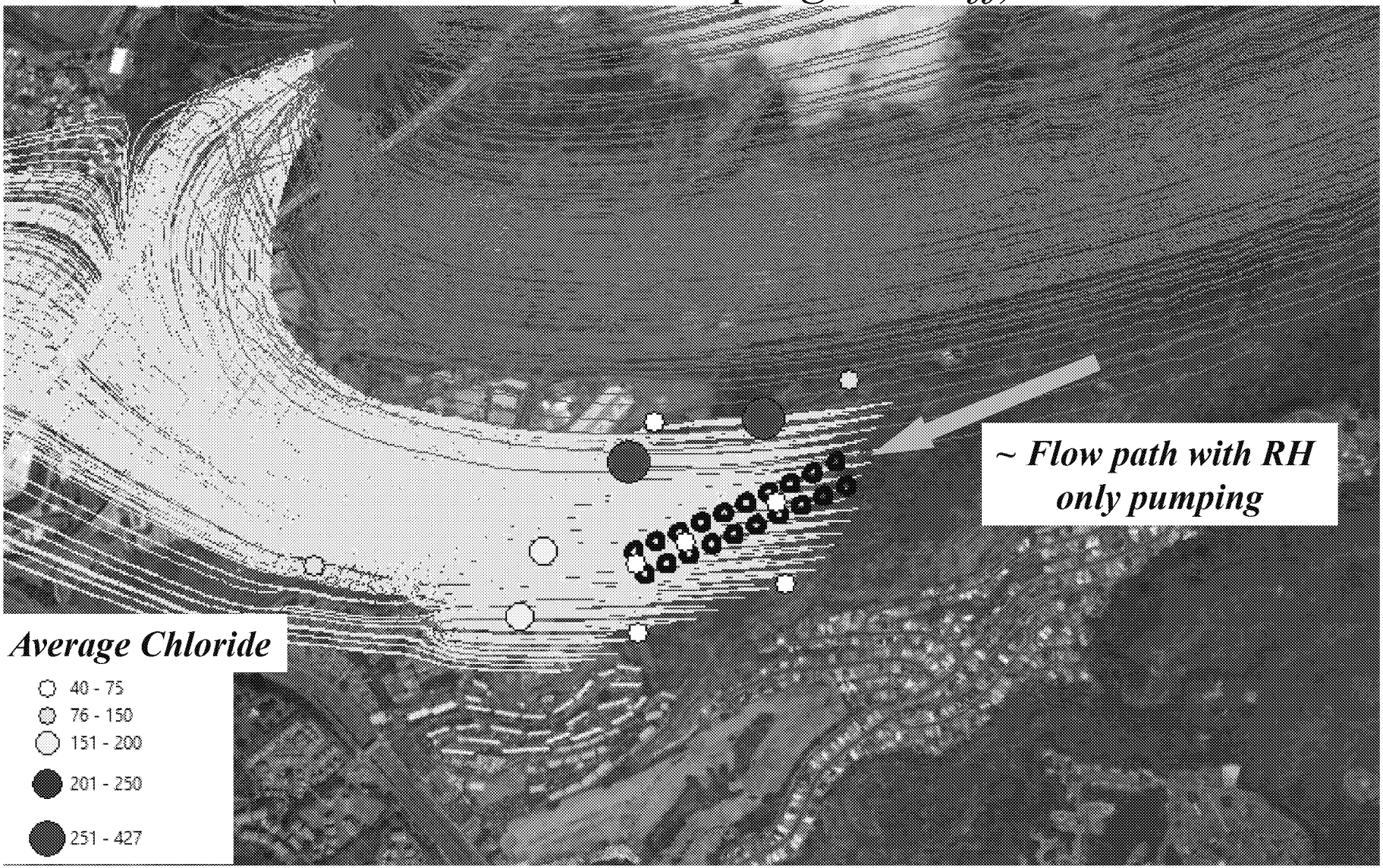
Modeled Gradients Are Too Large

(Red Hill area, no gradient change under pumping)



Chloride in Groundwater with Model 51A Paths

(BWS Halawa Pumping, RH Off)

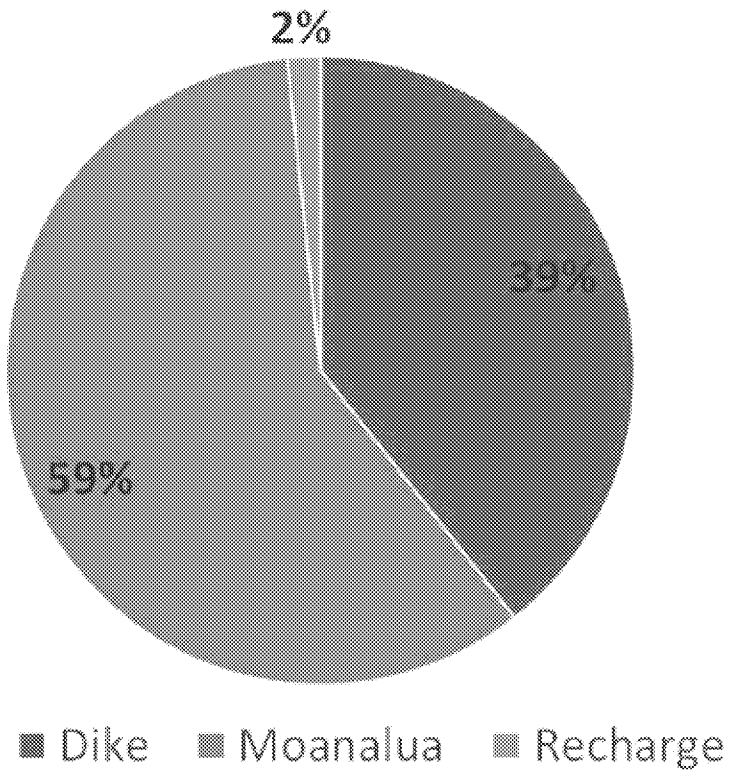


Geochemistry for Model Evaluation

1. What is the model going to be used for?
2. Do we have confidence that the model results are informative for that purpose?
3. Geochemistry for model evaluation
   a) Southeast Oahu chloride distribution
   b) Representative Red Hill vicinity chloride and nitrogen isotope distribution
   c) Red Hill Shaft chloride trends
   d) Southeast Oahu nitrate isotope distribution
   e) Implications of the nitrate isotope distribution for southeast Oahu groundwater flow trajectories

Unit Source Contributions to RHS

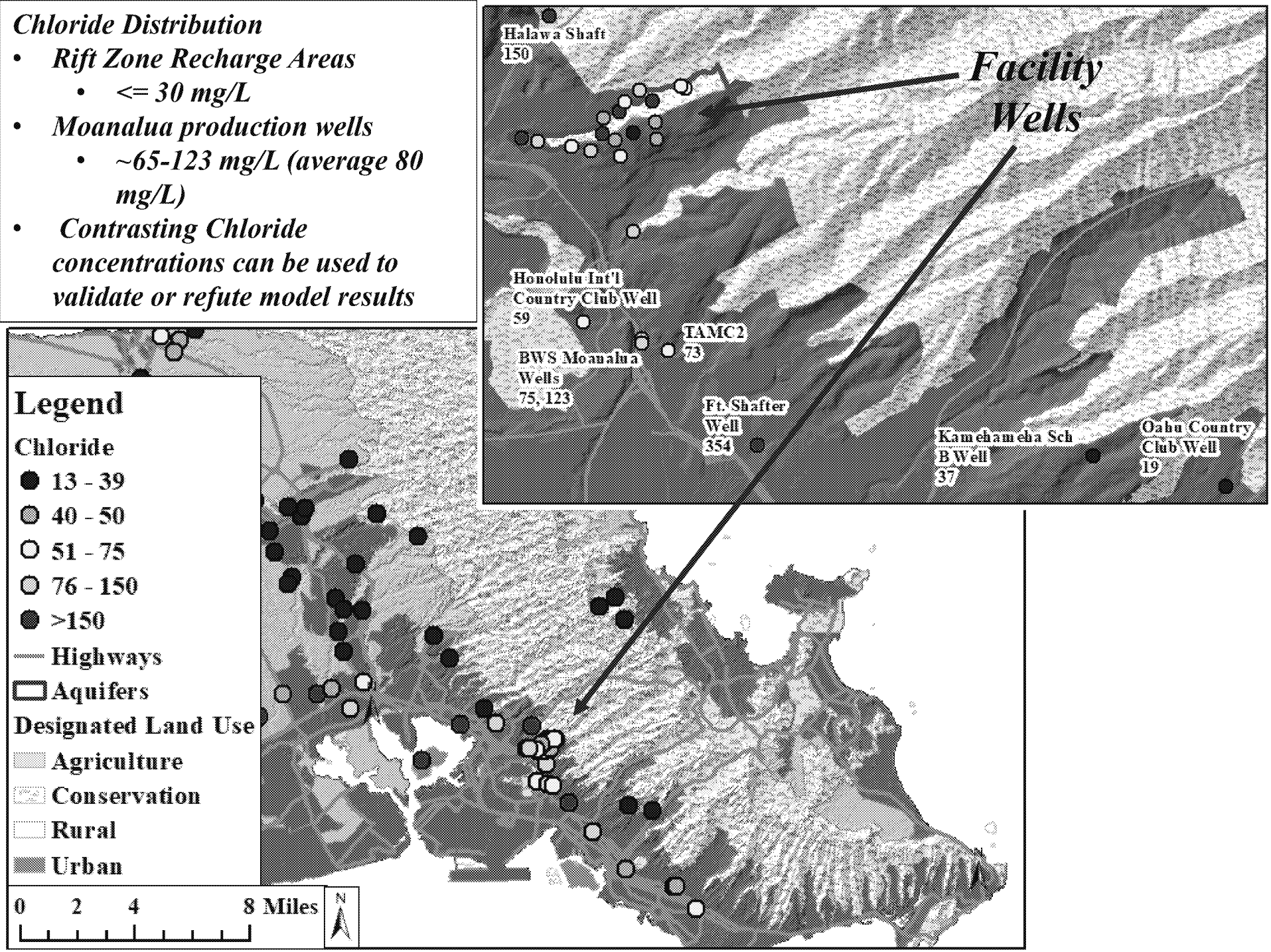
- "Unit source" mixing suggests contributions to RHS of the various sources of water as shown
- This scenario / graphic does not break out "upwelling" as a source at this time
- In this scenario, inflow from Moanalua is dominant: this results from efforts to match the apparent WNW gradient direction indicated by water level data



Provided for Discussion Purposes Only (05/07/2021)

Chloride Distribution

- *Rift Zone Recharge Areas*
  - *<= 30 mg/L*
- *Moanalua production wells*
  - *~65-123 mg/L (average 80 mg/L)*
- *Contrasting Chloride concentrations can be used to validate or refute model results*



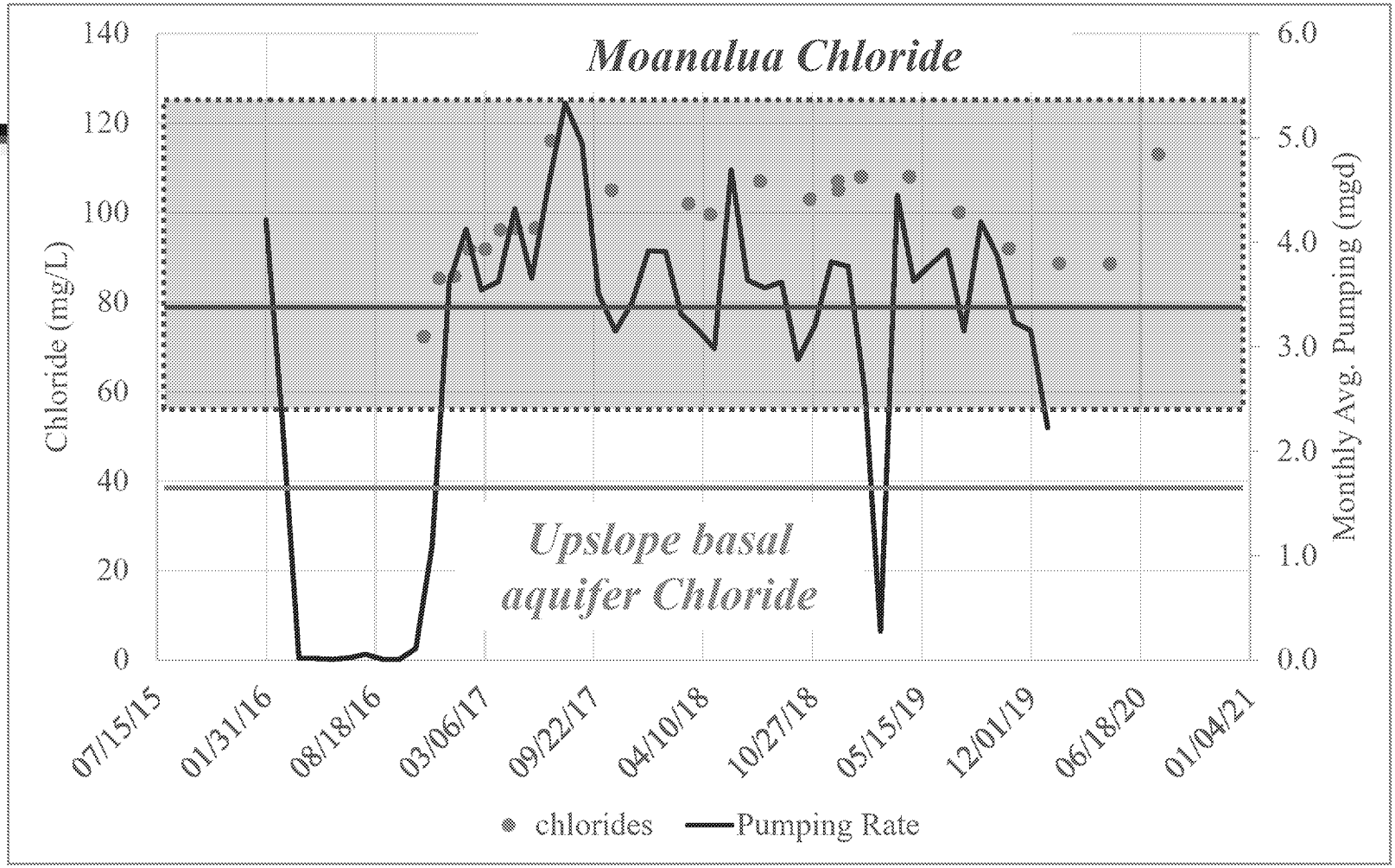
Comparative Chemistry

Chemical Parameter	Red Hill Shaft	Upslope Basal Groundwater*	Moanalua**	Comments
Chloride	95 73-130	37	82 (57-123)	
$\delta^{18}O$	-3.2 & -3.0	-3.1	-3.1 (-2.8 to -3.2)	RHS samples 1/9/17 & 4/23/20
$\delta^{15}N$	5.28	3.99	6.74 (6.15 & 7.33)	Natural dissolved NO_3 $\delta^{15}N$ ~ 2-3 $^{o}/_{oo}$

* ***Kamehameha School B well, upslope on Kapalama Ridge***

** ***Moanalua Wells 2&3, Tripler Army Medical Center Supply Well, Honolulu Int'l Country Club Well***

Groundwater in the dike zone recharge area would have [Cl] < 30 mg/L and $\delta^{15}N$ from 2 – 3 $^{o}/_{oo}$



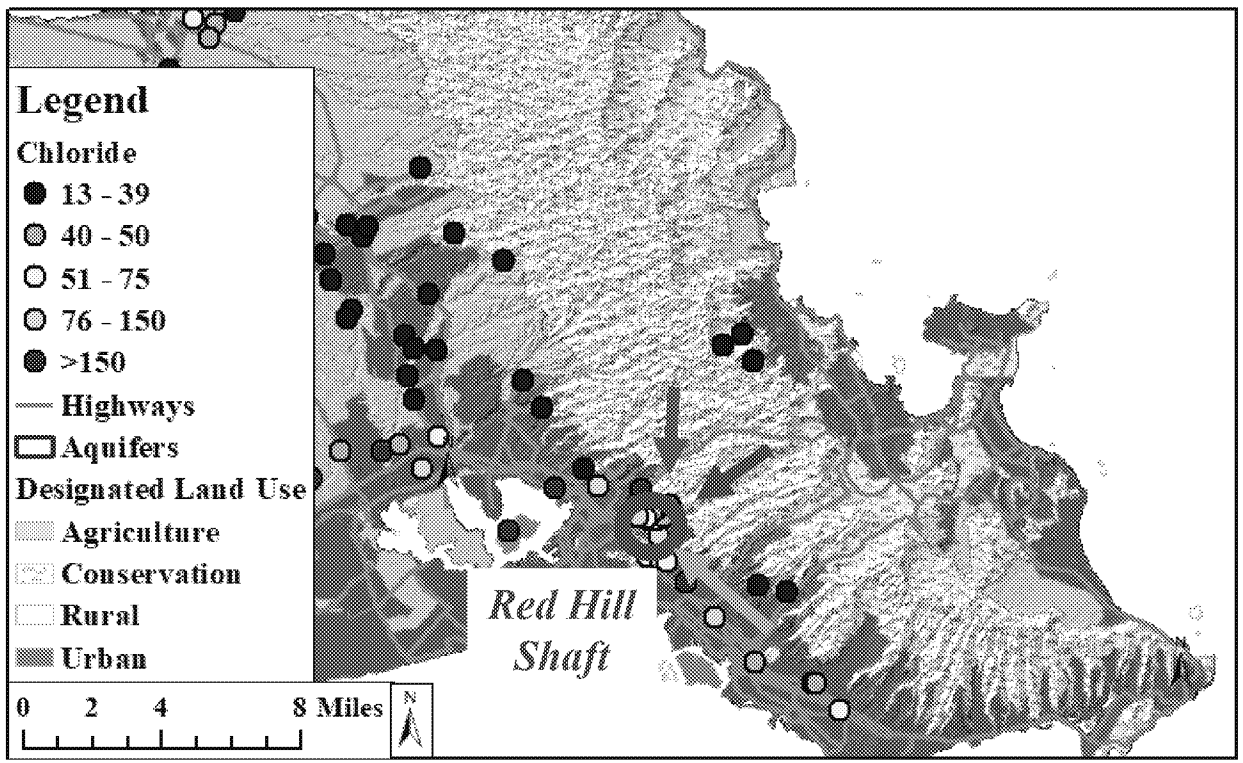
Chlorides were lowest at the end of the 2016 extended shutdown. Chlorides increased when pumping resumed. The Red Hill Shaft chloride concentration very close to that of Moanalua groundwater

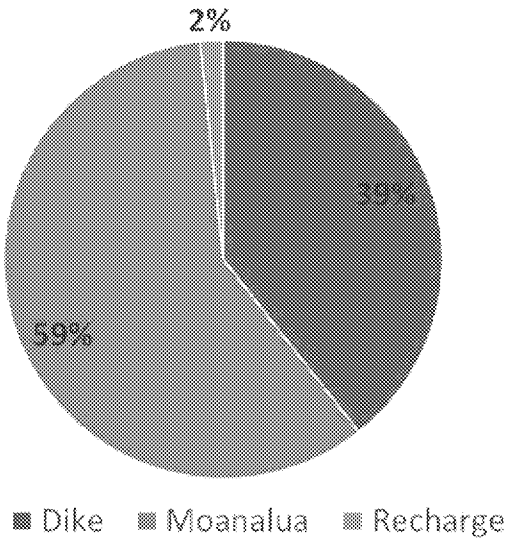
Incorporating Geochemistry w/o Doing a Transport Model

- Mixing Equation
  - $C_{mix}=(C_1*Q_1+C_2*Q_2+C_3*Q_3)/(Q_1+Q_2+Q_3)$
- Modeled inflow to Red Hill Shaft
  - Deep dike water – 39%; Cl=37 mg/L (NOTE: upslope basal groundwater)
  - Moanalua Water – 59%; Cl = 82 mg/L
  - Direct Recharge – 2%; Cl = 25 mg/L
- C_{mix} Calculated – 63 mg/L
- C_{mix} measured - ~95 mg/L
- This exercise is meant to be conceptual, and
- Informative
  - It is very difficult to account for the Red Hill Shaft chloride without have a significant amount of inflow from down or cross-slope

Incorporating Geochemistry w/o Doing a Transport Model

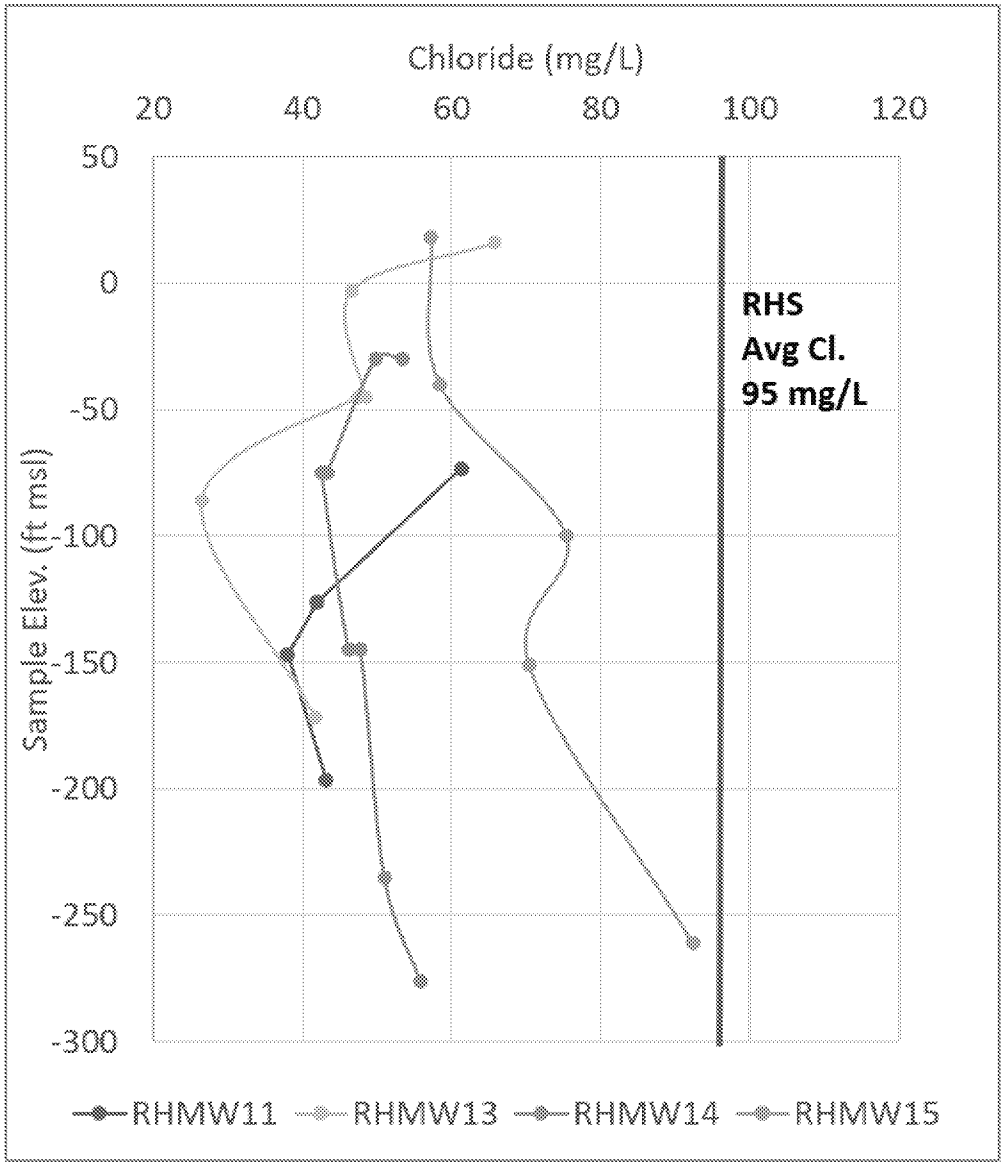
- Mixing Equation
  - $C_{mix}=(C_1*Q_1+C_2*Q_2+C_3*Q_3)/(Q_1+Q_2+Q_3)$
- Inflow to Red Hill Shaft
  - Chloride concentration is weighted Cl sum from the source areas



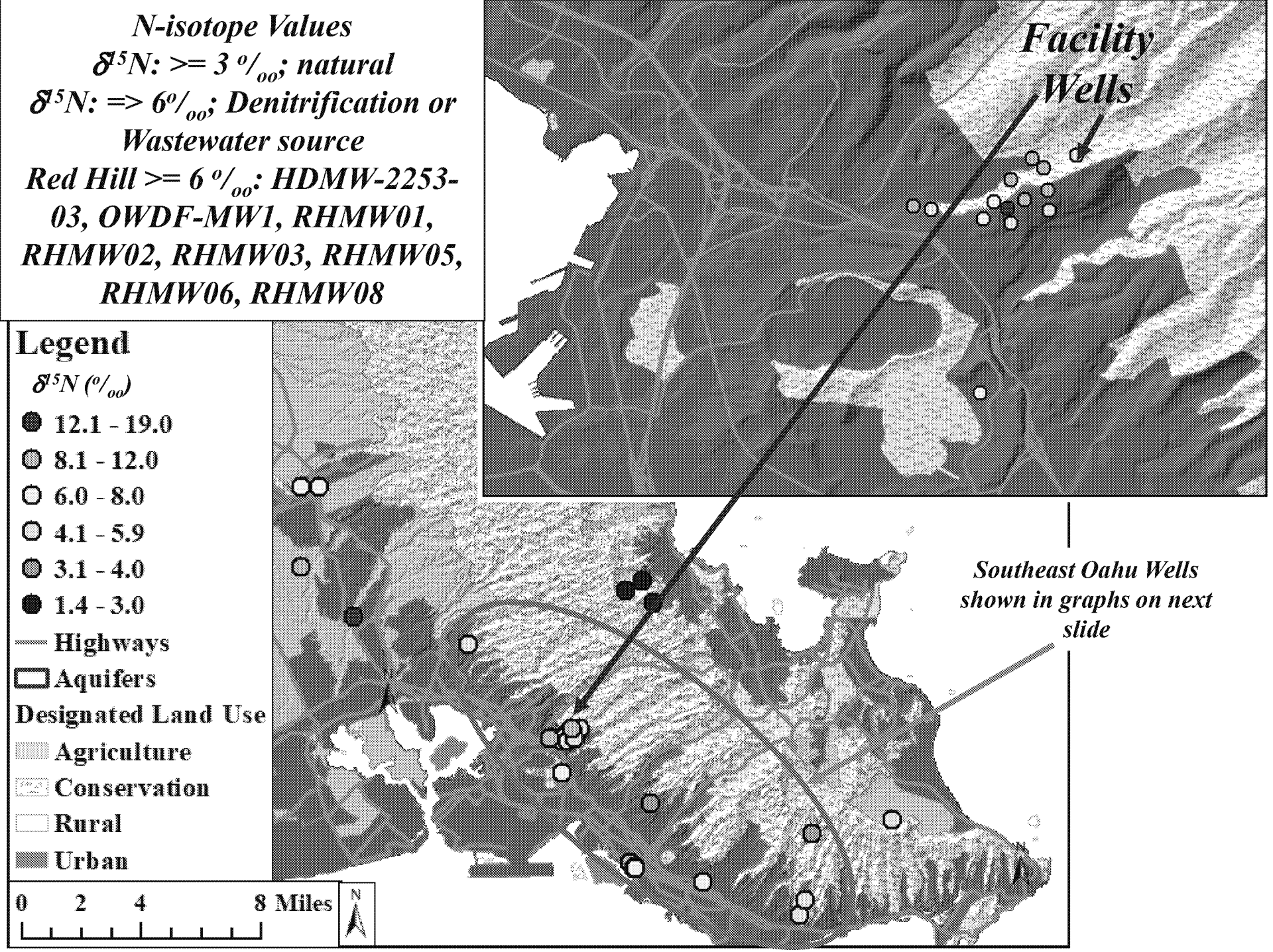


Westbay Well Chlorides

Source area for chloride



- Upslope of the Red Hill Facility all Cl<< RHS Cl_{avg} of 95 mg/L
- Low Cl in RHMW11, 13, & 14 argue against up flow from HDMW2253 as the source of Cl
- In RHMW15 (near the east end of the RHS infiltration gallery) the chlorides start to approach RHS values **only** at the deepest sampling port (-260 ft msl)
  - However, water levels indicate a downward gradient



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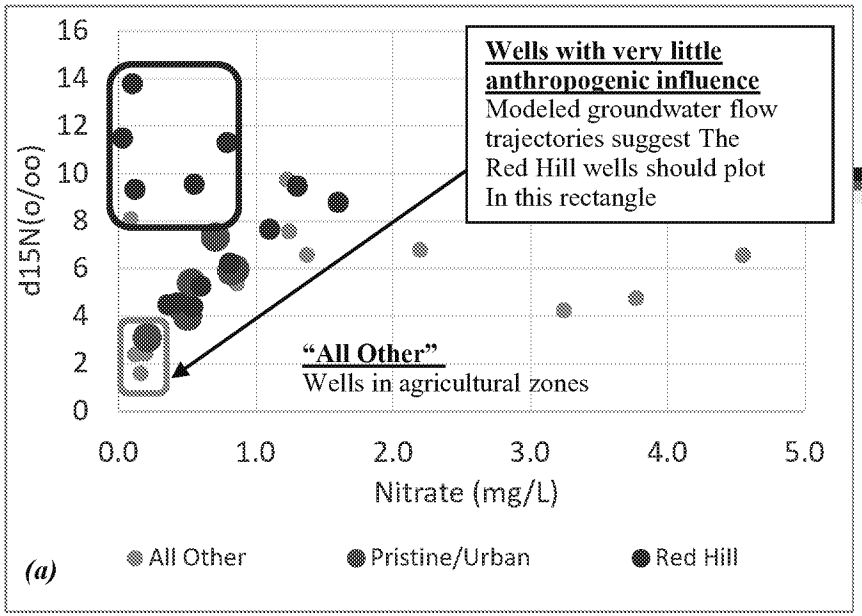
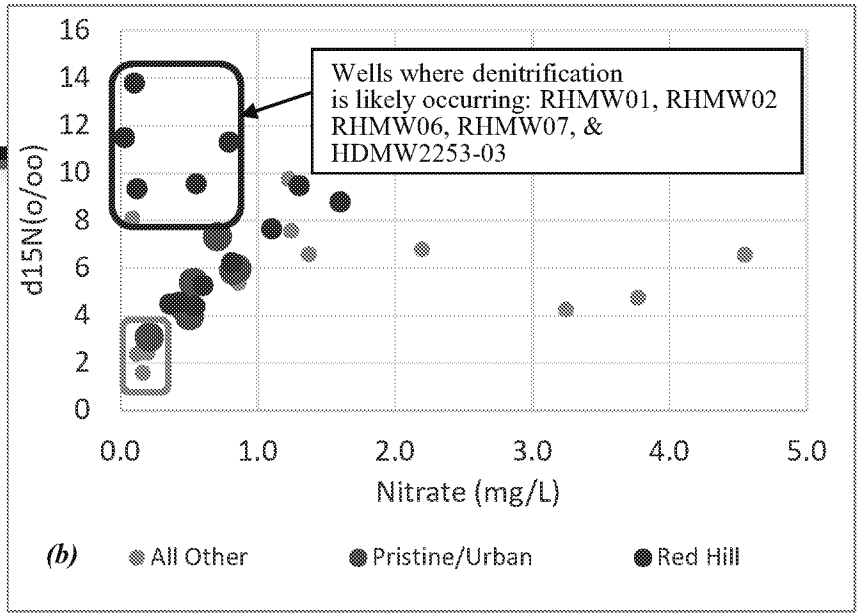
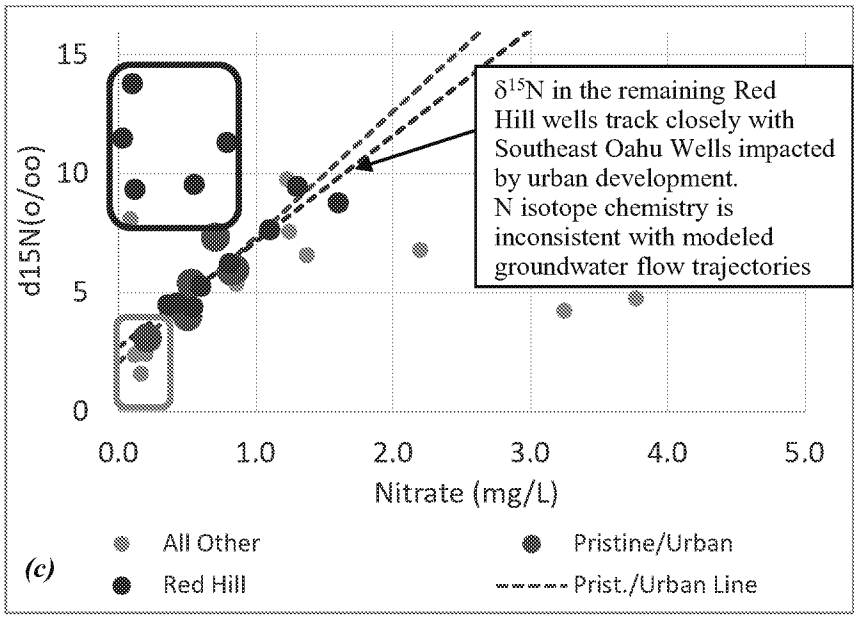


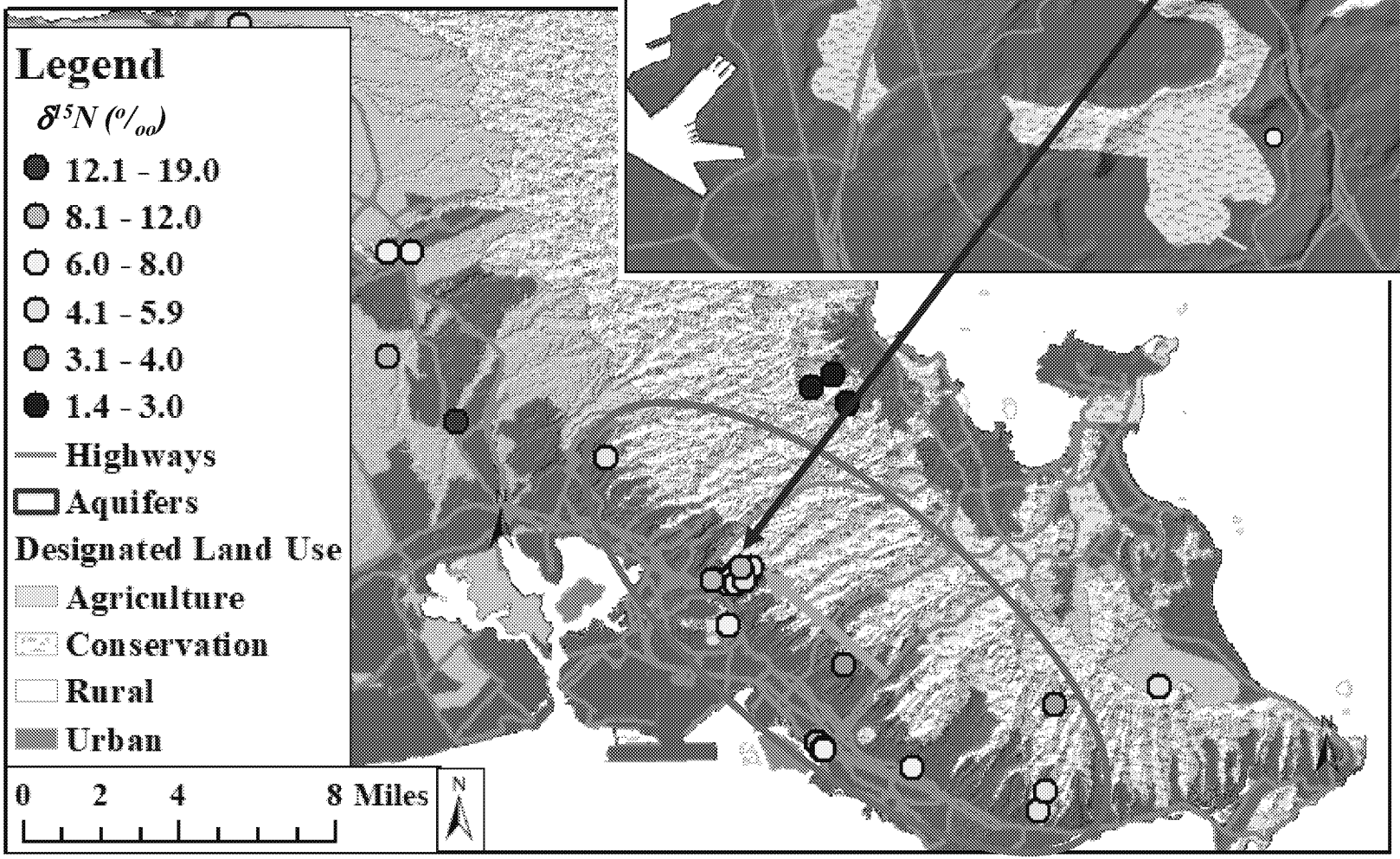




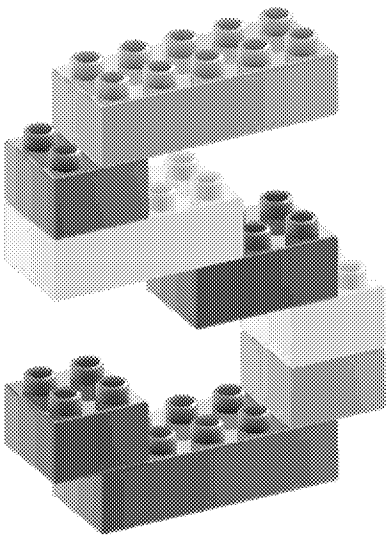
Groundwater nitrate aligns much better with cross-aquifer flow than with mauka to makai flow.

- ***Nitrate vs. $\delta^{15}N$ for groundwater samples collected on Oahu.***
  - ***The upslope groundwater has low [NO3] and low $\delta^{15}N$.***
  - ***Downslope groundwater has elevated [NO3] and elevated $\delta^{15}N$.***
    - ***Change in N chemistry due to anthropogenic impact.***
- ***Elevated [NO_3] and $\delta^{15}N$ in many Red Hill wells strongly suggest anthropogenic impact along the flow path***
  - ***Not consistent with modeled groundwater flow trajectories***

The nitrate concentrations and isotope chemistry strongly suggest cross ridge groundwater flow to the Red Hill Ridge.



Model Review Observations



- GWFMs do not match heads, diminishing reliability
  - In transient verification runs
  - Similar issue as in prior modeling (2007)
- GWFMs use atypical parameters for Hawaii aquifer
  - If retained, in depth justification needed
- GWFMs do not use CSM geologic details – SSPA work
  - Impact of heterogeneity needs further evaluation
- GWFMs do not comport with geochemistry
  - Complex distributions may imply multiple source waters
- GWFMs capture zones not supported by field data at pumping rates similar to those modeled
  - Parameters selected overestimate capture potential
  - Gradient issues & complexity not covered
- As the GWFM's currently stand, they are not reliable
  - For CF&T, risk analyses and mitigation decisions